On a Contrivance by which it is designed to measure Time automatically, in taking Star or other Transits. By Capt. J. Herschel, R.E.

There are two ways of effecting the object of this paper. The one is to describe all the parts of the proposed mechanism, leaving it to be inferred, or subsequently explained, in what manner they answer their several purposes, and conjointly secure the end in view; the other is to start with the object to be attained, and show how the requisite conditions may be met. The last will be here followed, as offering a better chance of perfecting the contrivance, as a whole, through the substitution of other mechanical artifices than those which present themselves as at first sight sufficient.

In observing a transit, as hitherto practised, the estimation of Time is an essential element, where by "estimation" is to be understood the combined operation of the senses and the intellect. The instant of an occurrence has to be estimated, and instruction transmitted to a recorder, automatic or other, to note the same. This complex series of duties is liable to miscarriages, from which the estimation of position is free. Is it not possible to obviate this? Cannot the passage of the star's image across the wire produce the same effect directly, as that which is now produced indirectly through the medium of the observer's senses, and exertion of nervous energy? Or if this is not yet attainable, cannot the observer be enabled to throw so much of himself into the work as to cause the arrival of something *material*, coincidently with the immaterial image; and *thereby* put in action at the moment of arrival the train of forces which mark the instant? This is practicable. Let a diaphragm with a single vertical wire be driven across the field of view at the same rate as the star, and (as regards the wire) coincidently with it. In its journey let it produce the contact which completes the galvanic circuit, and impresses the time-record on the chronograph. If this event takes place at a fixed stage in the journey, it is evident that the time will always be recorded when the wire is in a fixed place, and, therefore, since the wire is to be supposed to accompany the star, when the star is in that same place. This is equivalent to determining the instant of transit over a fixed wire. And it is perfectly automatic, for the observer is not concerned with it at all, except in keeping the star and wire accurately together during their journey across the fixed point.

But how is he to do this? The only answer is, that mechanism must be provided which will enable him. By releasing a wound-up spring acting on a fan through a train of wheels, the wire diaphragm must be drawn across at any rate not exceeding that of an equatorial star. If so released when the entering star reaches the wire, the two will travel across together—not necessarily coincident, but in close proximity. Further adaptation

must enable him to restrain, or urge forward with the needful delicacy, the moving frame and wire, and so effect an intersection as though both were stationary. While one hand is attending to this, the other will hold the contact-key which is to allow or forbid the record being made, according as the observer is satisfied or the reverse with the intersection he has made, at the time of reaching the stage where contact will take place. Of course there may be any number of such stages.

The traversing mechanism is, no doubt, that which will require most ingenuity. The work which it has to do is exceedingly light, and therefore it may be made with delicacy, and with due regard to the danger of perceptible vibration imparted to the tube. Attention may also be well bestowed on that part of it which regulates its mean speed. If possible the setting of the telescope should act directly upon it, so that (within the limits of N.P.D. which experience may show to admit of its action) the speed will in every position correspond, as closely as ingenuity can make it, with that of a star towards which the tube is directed. There is ample room here for the skill of a machinist; but there does not appear to be any insuperable difficulty, since all that is really requisite is a nearly uniform motion, susceptible of moderate intentional and subsidiary acceleration, or retardation (such as may be produced by a spring acting on the circumference of a plain wheel), and subject to gross regulation by previous adjustment. An arrangement will also be necessary by which the action of the machinery on the wire frame can be thrown out of gear, so that the latter may be quickly moved to any part of the field, to pick up a star that may have entered unawares. These difficulties are not underrated; but the very great importance to astronomy of any practical means of relieving the observer from the duty of estimating time minutely seems to make them worthy of being surmounted.

There does not seem to be any corresponding difficulty in arranging the parts which are to serve the essential purpose of recording the instant of transit of the *wire*—as distinct from that of the star which it represents. An isolated needle-point projecting from the sliding-frame, and isolated hair-springs projecting from its guide frame, seem to meet all the requirements. It is, however, conceivable that the personal equation, so to speak, of the battery may vary, owing to its greater strength at one time than at another. But it will certainly be constant for the whole of each transit, and will probably be under complete control eventually. As it would be highly desirable, indeed essential for transits below the pole, or with reversed pivots, that the mechanism should permit of the wire-frame being traversed in either direction, backwards or forwards, in order that the wire may likewise accompany a retrograde object, the needle-point and springs must come into action against each other indifferently on either side. This also will cause a "personal equation" which, it may be hoped, will not be difficult of determination.

Whether the above conception is or is not susceptible of practical realization, it is difficult to believe that the method could not be made to secure, in some such way, the desired result of a mechanical determination of time. If it can, it must prove of great value to an observer of transits, by relieving him of the duty of estimating *the time* of an event.

Bangalore, September 8th, 1870.

Prof. A. S. Herschel, in a letter dated Collingwood, June 14th, 1871, addressed to Mr. Lassell, and communicating to him the foregoing paper, writes:—

In the autumn of last year my brother also sent me a paper on a contrivance for automatic registry of the Times of Transit of a star, across the wires of a transit telescope. Until the paper had been submitted to some good practical mechanical and astronomical authority, my brother did not wish it to be communicated to the Astronomical Society. I then sent the enclosed copy of it to my late father, with the small drawings 1 and 2 (following it) of the Eye-end of a Transit-telescope, showing a contrivance of a revolving sphere, driven by clockwork and driving (by rubbing) the head of a micrometer-screw. By inclining the axis of the sphere at different angles to the axis of the screw, different rates of revolution of the screw might be obtained, corresponding very nearly to the different polar distances at which star transits would be observed.

On a second page a plan of a pair of "*Marlborough wheels*" is shown, with a moveable pinion engaging them both, and capable of being made to travel round them in either direction. When fixed, it transmits the power of the clock to the telescope (or to the micrometer-screw at the eye-piece), with a fixed velocity-ratio, depending on the proportion of the number of teeth in the two Marlborough wheels. When it is moved by the hand, in one direction, it increases, and in the other direction it diminishes, the velocity ratio of the Marlborough train; and it thus enables an observer to wait for, or to overtake, and thus to bisect a star.

The objection urged by my late father against any such construction for automatically registering the *Times* of transits, was, *that it burdens the eye-piece of a telescope* with cumbersome machinery, which is the part of the telescope that requires to be most light, and free from tremors. I also showed my brother's paper to Professor Grant, at Glasgow, who recommended its communication to the Astronomical Society. But before presenting it to you, I hoped to be able to obtain Mr. Airy's opinion of its merits, which my very close and constant occupation at Glasgow, during the last Winter Session, unfortunately prevented me from doing. I need scarcely add that my attempt to supplement the paper with a few mechanical contrivances is of no value or importance, compared to the *practical scientific interest* which attaches to my brother's original suggestions.

The drawings and explanations referred to in the letter were as follow:—

a is a bevel wheel driven with constant speed by a spindle *p* which comes down the tube of the telescope from a clock fixed upon one of the piers or pillars of the horizontal axis of the telescope. A long brass arm A turns on the axis of the wheel *a* as a centre, and carries another large bevel wheel *b* at its other end, which is driven from *a* by the intermediate pair of mitre-wheels

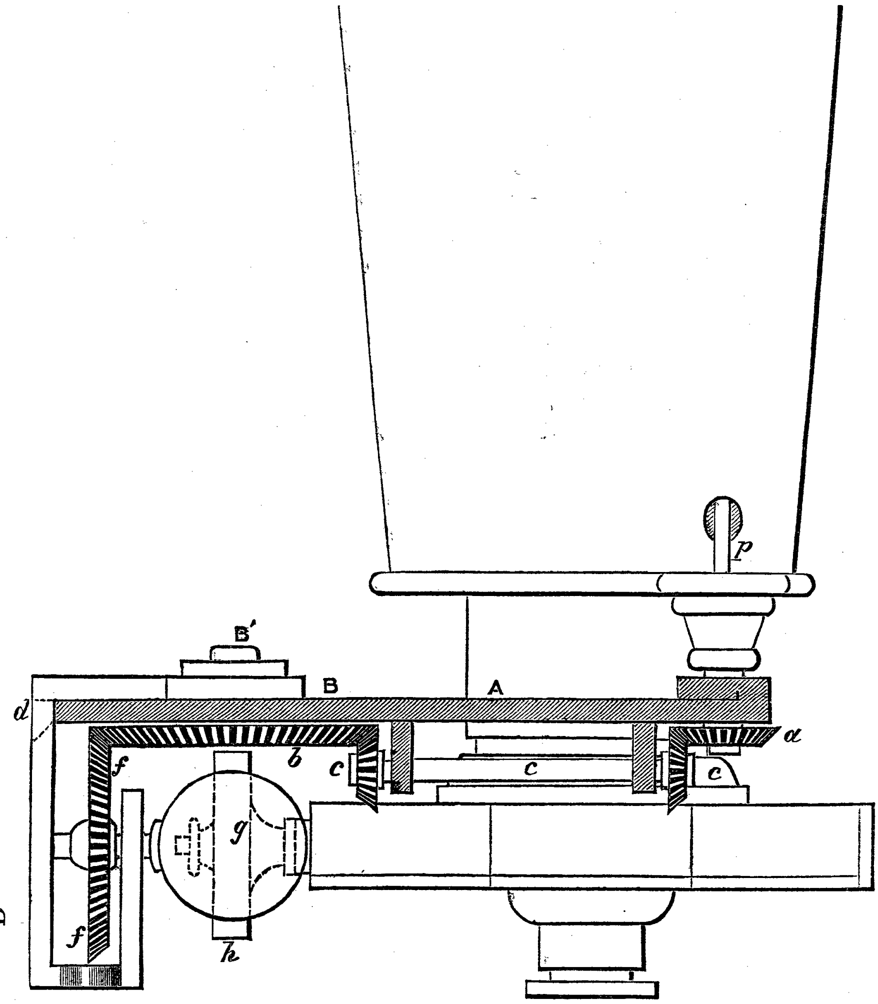

Fig. 1. View from above the Tube.

(*c c c*) on a common axis *c*, supported by the bar A. The latter ends at B in a circular plate B (a part of which is shown cut away at C, fig. 2, for lightness where it is not required); and B is pierced through its centre by the pin B′, which carries the bevel-wheel *b*, and also a brass plate, or radius, D, three times bent so as to carry the axis of another mitre-wheel, *f f*, which works in the teeth of *b*. This last axis carries the brass sphere *g*, which thus revolves with a constant speed, being wrought directly through the train of wheels, from the first clock-wheel *a*.

The sphere, *g*, rests with its whole weight, and with the weight of the lever A, and of its appendages upon the graduated head, *h*, of the micrometer, which is to be covered with an india-rubber band, and it will then be driven by the friction of the sphere. By turning the bent arm, D, round the pin B′, so as to give the axis of the sphere any degree of inclination to the vertical line, *g h*, fig. 2, corresponding to the N.P.D. of the star to be ob-

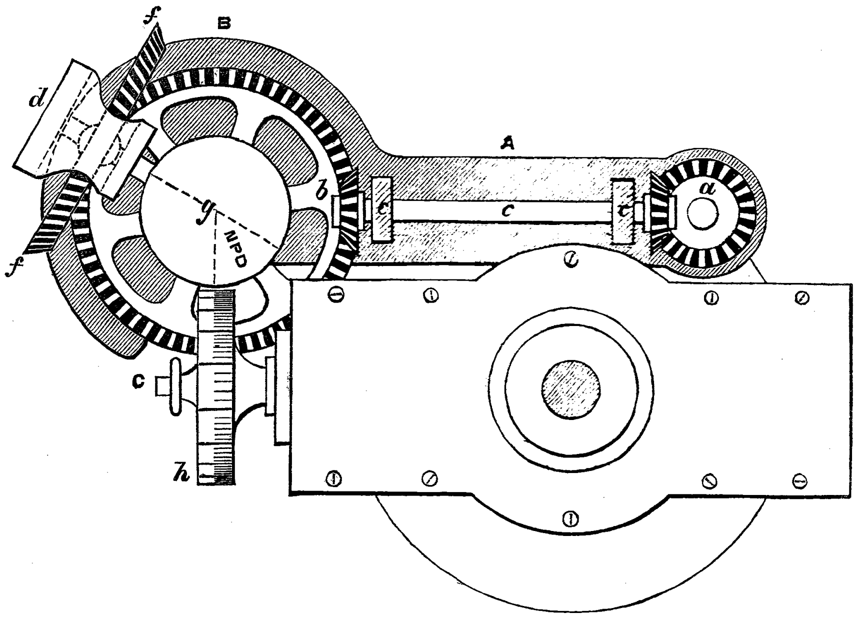

Fig. 2. Front, end view of the Tube.

served, the speed with which the sphere will drive the micrometer-screw head round, will be proportional to the speed with which the star will cross the field of view at that distance from the pole; and to facilitate placing the axis of the sphere at its proper inclination, the edge of the circular plate, B, can be graduated, and a vernier-aperture at *d* may be cut through the bent arm, D, so as to show the N.P. Distances to the nearest degree, or 15′, for which the sphere is to be set. A little adjustment by a fine tangent-screw would bring the speed of the wire-frame into exact coincidence with that of the star after it had entered the field of view, by a few trials. And the action of a smooth sphere upon a stout band of india-rubber would probably be very regular and uniform; or might, at least, be worth a practical trial.

Instead of the weight of the lever, A, and of its appurtenances pressing upon the head of the micrometer-screw, this part of the apparatus might be made as light as possible, and might be made to press uniformly against the head of the micrometer by means of an elastic spring.

A pair of Marlborough wheels (like those fitted by Messrs. Cooke to the clock-motion of Mr. Newall's large Equatoreal

telescope at Gateshead) placed in some part of the train of wheels between the clock and the telescope (see fig. 3), would enable an observer by turning a milled head, and thus making a pinion revolve backwards or forwards round the pair of Marlborough wheels, to retard or advance the motion of the sphere, g, and of

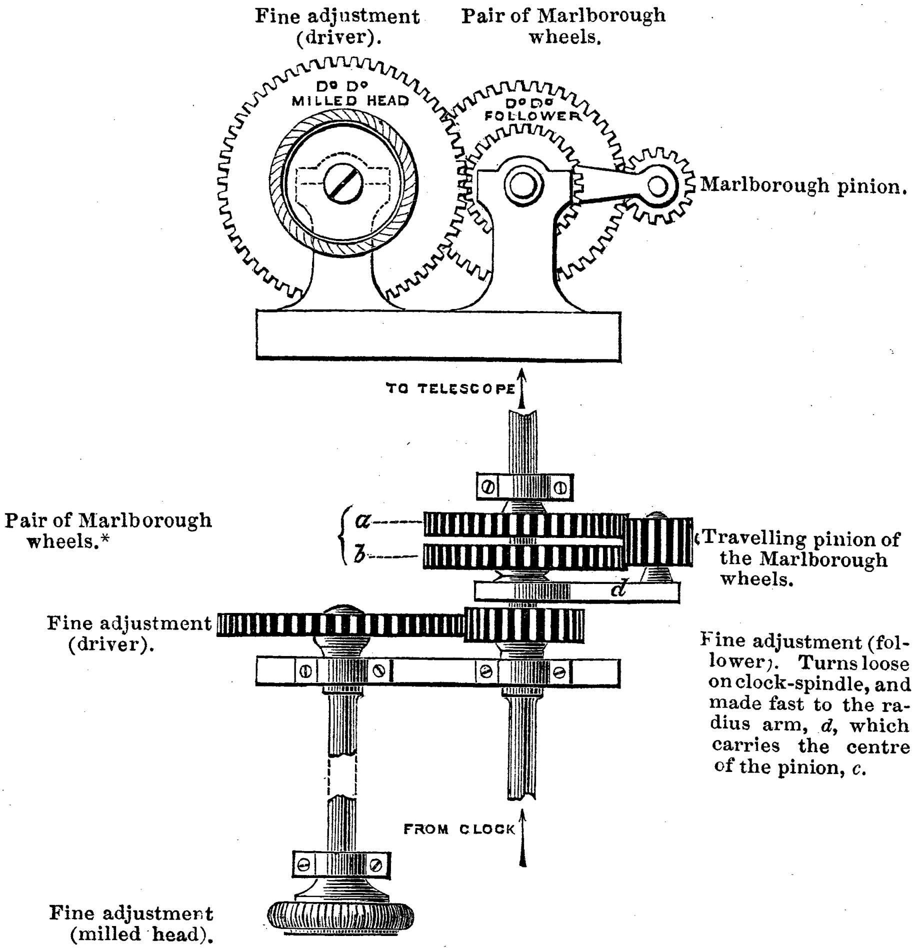

Fig. 3. Pair of Cooke's Marlborough wheels for advancing or retarding the motion of a telescope driven by clockwork, so as to give small adjustments in R.A.

the micrometer-screw which it drives in any manner; so as to make the micrometer-wire bisect the star. When the moveable pinion is left at rest, the motion of the clock is transmitted uniformly through the rubbing-sphere, g, to the wire frame of the micrometer, with the proportion of its speed exactly such as to

* The wheel a has a few more teeth than the wheel b, and moves slower than the wheel b, when the centre of the pinion c is fixed. When the pinion c is carried forwards round the two wheels a, b, the wheel a is also carried forwards, or it is made to advance. When c is turned backwards round the wheels a and b, the wheel a is also turned backwards, or it is made to return. The wheel a has the same diameter, and is on the same line of centres with b; and it has *so few more* teeth than b, that the difference of their pitch does not prevent both of the wheels from working equally well in the pinion c.

keep the star bisected by the wire as long as they remain together in the field of view. The frictional bearing of the sphere upon the screw-head will prevent the clock from over-winding and injuring the thread of the micrometer-screw if it should be inadvertently left in gear with it until the screw reaches the end of its range.

The Astronomer Royal remarks on the foregoing :—

Capt. Herschel's abstract idea, that a wire should be made by mechanism to accompany the star-image, and at a definite point should make a galvanic contact, is excellent. It implies the necessity of placing the wire on the star beforehand, and of giving the wire frame a motion agreeing *very accurately* with the motion of the star-image. And here is the practical difficulty.

Professor Herschel's mechanical plan for doing this is ingenious. But it implies, 1st, an original uniform motion (not easy to get); 2nd, motion through three engrenages of bevelled wheels (which would have abundance of shakes); 3rd, adjustible motion by the surface of a sphere rubbing a drum-head at different declinations on the sphere. (I doubt whether this can be made nearly correct enough, but it is very pretty.)

I do not think that the problem is by any means solved.

Note on the Curve traversed by base-end (remotest from fixed pivot) of the last prism of a Single or Double Automatic Spectroscope. By Richard A. Proctor, B.A. (Cambridge).

Writing down somewhat in haste the equations in the Note on page 206, I failed to notice that the polar equations to the curves traversed by the points P and Q (fig. 2, p. 207) can be very readily obtained. Thus let

$$\text{A P} = r \qquad \text{and} \qquad \angle \text{ P A O} = \theta.$$

Then θ is the component of $\angle$ D O A ; that is

$$\theta = \frac{\pi}{2} - 6 \sin^{-1}\left(\frac{a}{\text{R}}\right)$$

or

$$\sin\left(\frac{\pi}{12} - \frac{\theta}{6}\right) = \frac{a}{\text{R}} \qquad \text{(i)}$$

But

$$r = 2 \text{ R} \cos \theta;$$

hence (i) becomes

$$r \sin\left(\frac{\pi}{12} - \frac{\theta}{6}\right) = 2 a \cos \theta.$$

This is the polar equation to the locus of P. It may be written

$$r\left[(\sqrt{3} - 1) \cos\frac{\theta}{6} - (\sqrt{3} + 1) \sin\frac{\theta}{6}\right] = 4 \sqrt{2} \,.\, \cos \theta.$$

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